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Novel Design and Model of Punching Machine Driven By Electromagnetic Actuator

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***Abstract*——- The greatest challenge faced by an engineer is to overcome the energy wasted due to friction in any mechanical process. In a conventional punching process, mechanical or hydraulic force is used to operate the punch which involves large amounts of metal to metal contact in the drive system components, as well as inaccuracy in the control of the punching forces at the micro level. This paper introduces the basic construction of an Electromagnetic assisted punching machine to carry out the punching operation. The punching force is generated by an electromagnetic coil wound around a metal core. Since the proposed design replaces Mechanical or hydraulic drive with an electromagnetic actuator, the setup is capable of perfectly controlling the force generated by the controlling the power supplied. The micro punching setup is designed to punch small parts at a precisely controlled rate of power consumption and thus the process becomes a low friction, high efficiency process. After successful fabrication, the setup was tested and the punching force produced was validated. The punched samples were further analyzed optically for any defects such as burring and those results were documented.**

***Index Terms*——Energy, Friction, Punching, Mechanical force, Hydraulic Force, Electromagnetic actuator, current, High efficiency, Burring.**

I. Introduction

Punching is a metal forming process that uses a punch press to force a tool, called a punch, through the work piece to create a hole via shearing. The punch often passes through the work into a die. A scrap slug from the hole is deposited into the die in the process. Depending on the material being punched this slug may be recycled and reused or discarded.

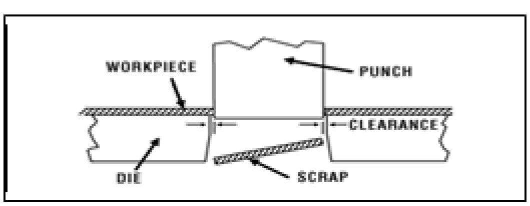

Fig. 1 Schematic Diagram of Punching Process

Punching is the cheapest method for creating holes in sheet metal for medium to high production rates. In forging applications the work is often punched while hot, and this is called hot punching. A punch is often made of hardened steel or carbides. A die is located on the opposite side of the work piece and supports the material around the perimeter of the hole and helps to localize the shearing forces for a cleaner edge. There is a small amount of clearance between the punch and the die to prevent the punch from sticking onto the die, and so less force is needed to make the hole. Some punching machine drives in existence are flywheel, mechanical punch press and hydraulic punch press.

A.Flywheel drive

Most punch presses today are hydraulically powered. Older machines, however, have mechanically driven rams, meaning the power to the ram is provided by a heavy, constantly-rotating flywheel. The flywheel drives the ram using a Pitman arm. In the 19th century, the flywheels were powered by leather drive belts attached to line shafting, which in turn ran to a steam plant. In the modern workplace, the flywheel is powered by a large electric motor.

B.Mechanical punch press

Mechanical punch presses fall into two distinct types, depending on the type of clutch or braking system with which they are equipped. Generally older presses are “full revolution” presses that require a full revolution of the crankshaft for them to come to a stop. This is because the braking mechanism depends on a set of raised keys or “dogs” to fall into matching slots to stop the ram. A full revolution clutch can only bring the ram to a stop at the same location-top dead center. Newer presses are often “part revolution” presses equipped with braking systems identical to the brakes on commercial trucks. When air is applied, a band-type brake expands and allows the crankshaft to revolve. When the stopping mechanism is applied, the air is bled, causing the clutch to open and the braking system to close, stopping the ram in any part of its rotation.

C.Hydraulic punch press

Hydraulic punch presses, which power the ram with a hydraulic cylinder rather than a flywheel, are either valve controlled or valve and feedback controlled. Valve controlled machines usually allow a one stroke operation allowing the ram to stroke up and down when commanded. Controlled feedback systems allow the ram to be proportionally controlled within fixed points as commanded. This allows greater control over the stroke of the ram, and increases punching rates as the ram no longer has to complete the traditional full stroke up and down but can operate within a very short window of stroke.

II. Problem Statement

Until now punching operations have been carried out by utilizing the force developed by mechanical and hydraulic

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forces. These approaches have several drawbacks which include a significant loss of energy due to friction and inability to precisely control process parameters. This paper proposes an approach that aims to provide the force required for punching by electromagnetic attraction. By manipulating electromagnetic attraction, frictional losses are drastically reduced. The electric supply can be accurately controlled to generate the correct amount of force required. In adopting this method, an innovative method to punch the surface of a given material is employed. The force produced by electromagnetic attraction is transmitted to the punching tool by means of push rods. The punching tool strikes the workpiece against a die, creating the required perforation.

III. Design Methodology

The punching machine consists of a punching tool, die, push rods, transverse beam, return springs and an external support structure. A switch is connected between the DC power supply and the windings of an electromagnet. When the setup is connected to a 230 volt, 2Amps DC supply, the coils are supplied with electricity and the magnetic field is developed around the coil. The electromagnetic core which is within the magnetic field gets magnetized and in turn it exerts a force proportional to the electricity and attracts the transverse beam. The mild steel plate is connected to the ends of a punching tool through two push rods. Thus when the plate moves towards the core, the push rods transmit the motion onto the punching tool with the same force developed by the electromagnet. The punching tool moves toward the die block and punches the surface of the work piece. The tool and work piece are then separated by means of two return springs. The springs are initially compressed during the forward stroke. When the electric supply is cut off, the magnetic field ceases to exist and after the electromagnet loses its magnetization, the spring retracts,

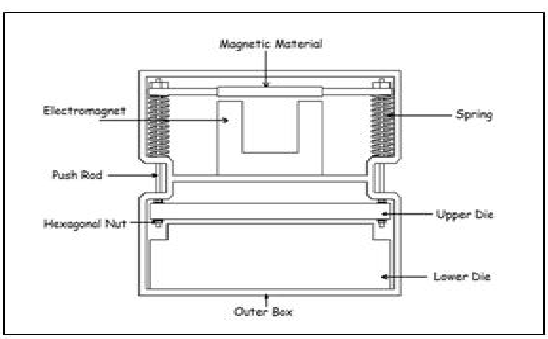

Fig. 2

moving the punching tool away from the work piece and the cycle is completed. The punched work piece is removed from the punching machine and another is loaded onto the die block in its place. This procedure is repeated in order to obtain subsequent punches.

IV. Design calculation

A. Electromagnetic Force Calculations

The following dimensions were suitably taken for the metal core which will form the support for the two coils. No procedure was followed in designing these dimensions. Instead, the coil will be designed based on the dimensions chosen for the core.

Flux produced = Ampere Turns * Total reluctance

Magnetic field B = Flux produced / Area of core

Force produced = $B^2A/2\ \mu 0$

Total Force = 2 * Force produced

Ampere Turns (AT)… Amp	15000
I… Amp	2.50
N… turns	6000
Flux… webs	0.000790108
B… Tesla	1.330
Force… N	418
Total Force… N	836

Coil Resistance = Voltage * Current / 2

Wire diameter = Area of cross section * 1.273

Wire selection: 26 SWG diameter = 0.457mm

Resistance of the wire = Resistance per meter * total length of wire.

Resistance per meter at 20deg	0.1043
Required Turns per coil	3000
Mean turn length… m	2.5000
Total wire length… m	7500
Resistance of wire	781.88

B. Push rod design

1) Material: mild steel/carbon steel

2) Properties: Young's modulus E = 200 GPa

Yield stress σ_y = 400 MPa

3) Safe Stress/Proportional Stress $\sigma_{pl} = (0.5 \sim 1)\sigma_y$

σ_{pl} = 200 MPa

4) Calculations: Direct Stress on column assuming a load of 400N

$$\sigma = P/A$$
$$= 400/3.14 \times 0.009^2$$
$$= 1572697.96 \text{ Pa}$$
$$= 1.57 \text{ MPa}$$

This is within the allowable stress of 200 MPa

Height of pushrod L= 100 mm

Radius of pushrod r= 10 mm

5) Critical slenderness ratio:

Slenderness Ratio = L/r = 100/10 = 10

$$SR_c = \left(\frac{L_{eff}}{r}\right)_c = \sqrt{\frac{E\pi^2}{\sigma_{pl}}}$$

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SRc =99.3
As slenderness ratio is within limits the design is safe

C. Magnetic beam design:

1) Material: mild steel/carbon steel
2) Properties: Young's modulus $E = 200$ GPa
Yield stress $\sigma_y = 400$ MPa
3) Safe Stress/Proportional Stress $\sigma_{pl} = (0.5 \sim 1)\sigma_y$.
$\sigma_{pl} = 200$ MPa
4) Calculations: Assuming the part to be a simply supported beam with point load of 800N at centre we can design the beam as follows:

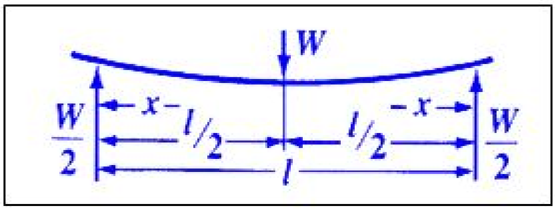

Fig. 3

Maximum allowable deflection we take as 0.1 mm
Deflection of the beam is given by at the centre:

$$\frac{Wl^3}{48EI}$$

$= (800 \times 0.2^3) / (48 \times 200 \times 10^9 \times 0.04 \times 0.01^3 / 12)$
$= 0.0002$ mm
Hence the deflection is within limits and design is safe.

V. Fabrication Process

A. Raw Material Purchase

The first step involved in the fabrication process is the acquirement of all the required raw materials. Mild Steel is the material used for most of the components. High Carbon High Chromium Steel and EN 24 Steel are also obtained. After obtaining all the required raw materials, the various parts are machined.

B. Fabrication of rectangular components

The various rectangular components like transverse beam, top cover plate, bottom cover plate and side plates are machined to the required dimensions using a shaper. Then surface grinding is done to enhance the finishing of the components. Holes are drilled into the surface by the process of jig boring. Internal threads are cut onto the plates by tapping operation. Finally, blackening is done on the components. Blackening is a heat treatment process which improves the surface hardness of the components.

C. Fabrication of cylindrical components

The various cylindrical components such as spring bush, push rods and core pins are machined to the required dimensions on a centre lathe using turning and facing operations. Drilling operation is done on the spring bushes. Cylindrical grinding is done on the components to improve surface finish. A heat treatment process called blackening is done to improve surface hardness.

D. Purchase of accessory parts

The readymade components such as screws, nuts, bolts, washer and dowel pins are purchased from the market. Readymade springs were purchased based on the spring design. The core winding was done externally based on calculated specifications.

E. Fabrication of punching tool setup

The punching tool setup comprises of the punching tool, stripper bush and dies. The components are machined to the required dimensions on a centre lathe by turning and facing operations. Cylindrical grinding is done to improve the surface finish of the components. Surface grinding is done on the punching face of the punching tool to sharpen it and improve the punching action.

F. Assembly of fabricated parts

The plates are assembled around the punching setup with the aid of screws and bolts. The electromagnetic core is placed on the top cover plate and fastened using screws. The push rods are connected to the punching setup on one end and the transverse beam on the other. The core winding is placed around the electromagnetic core. The spring bushes and springs are placed around the push rods. The transverse beam is held in place with the help of washers and screws. The ends of the wires of the core winding are connected to a 230 volt, 3 amp electric supply. The assembled setup is now ready for use.

Fig. 4 Assembly of Fabricated Parts

VI. Components Description

A. Punching Tool:

The punching tool is made of High Carbon High Chromium Steel. It is used to punch the hole in the given work piece. When the work piece is kept in position, the punching tool strikes the surface of the work piece and creates the required hole(Dimensions: Diameter = 10mm ,Length = 70mm).

B. Electromagnet Core:

The electromagnet core is made of Mild Steel. The force required for punching is obtained by manipulating the

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attractive force developed by the electromagnet. When electric supply is given to the electromagnet, it gets magnetized temporarily and attracts the transverse bar with great force. This force is transmitted to the punching tool, which in turn punches the work piece and creates the hole. Following this, the electric supply is cut off and the electromagnet gets demagnetized (Dimensions: Diameter = 20mm, Length = 70mm).

C. Core Winding:

The winding is done using copper wire. When electricity passes through these wires, it develops a magnetic field according to Faraday's left hand rule. The magnetic field produced by the winding, magnetizes the electromagnet. The electromagnet core now behaves as a powerful magnet and attracts the transverse beam above it as the beam is made of magnetic material. The force of attraction produced can be altered by adjusting the number of turns in the winding and by adjusting the electrical supply given. This force produced is transmitted to the tool for the required punching operation (Dimensions: No. of turns/Coil = 3000, thickness of wire = 26 gauge, No. Of Coils = 2).

D. Spring:

The spring is made of Stainless Steel 304. The purpose of our spring is twofold. After the punching action, the spring is used as a return mechanism to push the punching tool up. When the tool has successfully punched the work piece, electrical supply to the electromagnet is cut off. The compressed spring now exerts force on the transverse bar and lifts it up, enabling the operator to remove the work piece and load another. Before punching, the spring keeps the transverse bar and punching tool up, so that the work piece can be loaded without hindrance (Dimensions: Outer diameter =27.5mm, Wire diameter =4.0mm, Height = 42mm).

E. Transverse Beam:

The transverse beam is made of Mild Steel. Mild Steel was chosen as it is a magnetic material. When the electromagnet gets magnetized, the transverse beam gets attracted to it.

Fig. 5 Punching tool, electromagnet core, coil

Fig. 6 Punching tool, electromagnet core, coil

It moves toward the electromagnet with great force and this is the force used for punching (Dimensions: Length = 255mm, Breadth = 50mm).

F. Push Rod:

The punching tool is made of EN24 Steel. The function of the push rods is to transmit the force developed by electromagnetic attraction on the transverse bar to the punching tool. When the beam moves downward, the push rods move along with the beam with the same force and provides it to the punch tool which in turn punches the work piece.(Dimensions: Diameter = 20mm, Length = 130mm).

VII. Result Analysis

The punched pieces were analyzed under an optical microscope to check for burrs. The following images were obtained. The fig.7 shows 50X magnified view of one part of the punched hole and Fig.8 a dark field image of another part of the same punched hole under 100X magnification respectively. Burring is not visible. Fig.10 shows a dark field image of 200X magnified part of the punched hole. Only at this level burring is seen.

Advantages

- Friction loss is very minimal due to very little metal-metal contact in the drive system.
- The force created per punch can be controlled precisely as it is an electrical process.
- It is a compact device.
- It is portable.
- Variety of operations can be performed by just using different dies i.e. it is a flexible setup.

Fig. 7

Fig. 8

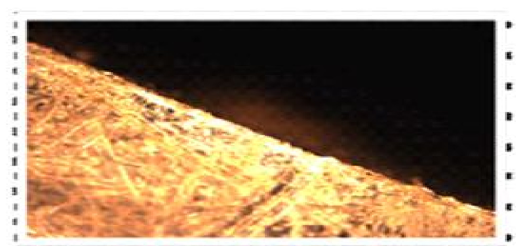

Fig. 9

VIII. Conclusion

The electromagnet-assisted punching setup is a device which uses the principles of electromagnetic attractions combined with a mechanical few mechanical elements to punch a hole on the surface of a given sheet of material form or shape a given material to desired shape. It is a very flexible process with the frictional effects reduced to the maximum

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possible extent. This is a significant improvement from the currently existing mechanism for punching. As well as being a portable and a compact device,

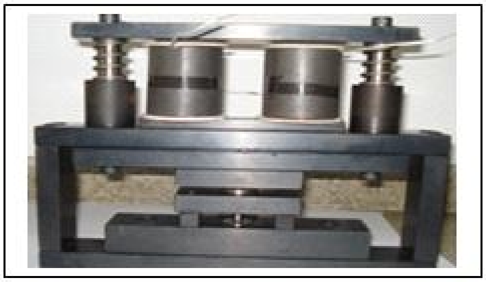

Fig. 10 Final Assembled Model

the power consumption of the setup is also controlled accurately as electrical energy is used. By varying the electric supply provided the force generated from the machine can be altered. For delicate materials which cannot withstand a heavy impact, a relatively small amount of current is supplied to the machine. This will help to develop the optimum force required to punch the work piece without damaging it. For sturdier materials, higher values of current are provided. This enables the punching machine to develop the required force to punch a hole of the surface of the work piece. The electromagnet-assisted punching mechanism that has been we have developed is the tip of the iceberg in terms of scope for the process in general. It has the capability to be extended onto many fields and superseding many existing forms of work forming.

IX. Future Improvements And Innovations

The electromagnet-assisted punching mechanism, though an innovative and a breakthrough process, has potential for various improvements and innovations in the future various limitations in terms of viability for mass production, cost efficiency and performance efficiency. The following improvements and developments are suggested to transform the punching setup into a sustainable and efficient process: Therefore, we offer a scope for improvement and development of this process into a more viable one by directing future efforts into one of the following methods.

a) Using a magnet instead of a magnetic substance as the transverse beam , when the current direction is reversed the magnetic force direction will also change and thereby the return stroke can be achieved without the use of a spring.
b) If an AC supply is coupled with the above principle a vibratory motion can be achieved and this will also find good use in suitable applications. we would be able to oscillate the polarity of the electricity
c) An auto feed mechanism can be orchestrated into this setup to provide greater scope for mass production. If we can accommodate the auto feed mechanism is synchronized to time with the frequency of the punch stroke then it we should be theoretically be able possible to achieve fast speeds in punching which would make it viable in industries both economically and in terms of process efficiency.

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